GENERAL PRACTICE EFFECT OF SPECIAL EXERCISE.

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Somewhere in the course of a lecture on the Relation of Natural Science to General Science, Helmholtz speaks of the advantages possessed by certain studies as "means for training the intellect, inasmuch as they tax equally all the intellectual powers," and this belief in the general disciplinary value of certain studies,—the greater or less efficacy of certain kinds of intellectual work as mental gymnastic—probably forms the *raison d'être* for education in the minds, not only of most laymen, but perhaps of most teachers of the present time, though what may be the factors entering into this disciplinary process is a question which usually receives a broad or vague answer. But of late years, under the title of formal discipline, the tenet has lost considerably in dogmatism and gained somewhat in definition, so that it has become a subject for experimental investigation. The present article is a contribution to this aspect of the subject, *i. e.*, whether it can be shown by direct experiment that the improvement acquired by practice in one kind of mental activity is induced in some other kind, more or less remote.

The greater part of the literature of the subject has been too frequently thrashed out to need further mention here. Of the less commonly quoted, articles which bear directly on the question may be cited, 1st, Urbantschisch's investigation in *Pflü. Arch.* Bd. 42, in which he showed that the influence of a sound stimulus is to lower the limens for light, smell, taste and dermal sensations; 2nd, Epstein's work, published in *Zeit. f. Biol.* Bd. 33, indicating that a sound stimulus heightens visual acuteness and sensitiveness to color, and 3rd, Vogt's research on Distractibility and Habituation in Kraepelin's *Psy. Arb.* Bd. 3, demonstrating that habituation to a distraction acquired in one exercise may be carried over to other exercises. There remain, however, two investigations, which, being of more recent date, have passed less frequently through the critical mill and therefore call for more detailed examination; Ebert and Meumann's extended research on certain fundamental questions connected with memory practice in *Arch. f. d. ges. Psy.*, Bd. 4, and Thorndike and Woodworth's work on the "Influence of Improvement in One Mental Function upon the

Efficiency of other Functions," in Vol. 8 of the *Psy. Review*. The treatise of Ebert and Meumann is an investigation of the induced effects of one kind of memory training on other kinds of memory carried out according to the "test" method. More especially, "a cross section" of memory was taken, determining the efficiency of the several memories for meaningless syllables, letters and numbers, one-syllabled substantives, foreign words (Italian), stanzas of poetry, visual signs, and prose. The reagents were then trained on meaningless syllables, when another "cross section" of memory was taken, to test both immediate and permanent retention. The tests indicated that the special training had increased the efficiency of all the several kinds of memory and that for the kinds of memory most closely allied to the test processes, the increase in efficiency was greatest. Thus, the authors state that the training increased the efficiency of memory for retaining philosophic prose 70%, and the memory for visual signs—a process certainly very unlike the training process with meaningless syllables—showed an increase in efficiency of over 55%, (*Arch. f. d. ges. Psy.*, 4: 182). In fact the increase in memorizing ability for all kinds of memories was so great that the reagents came to designate the training process as "memory cure." It is to be regretted that the authors did not carry on a "control" experiment along with their tests to ascertain the training effect of the tests themselves and to throw additional light on the changes taking place in the training intervals. Nevertheless, the investigation indicates pretty clearly that the training of a special memory increases the power of memory in general. The answer to the question how the learning of meaningless syllables increases the efficiency of all other kinds of memory is answered by the authors with an explanation involving a sympathetic practice effect of allied memory functions through a hypothetical psychophysical action. But as G. E. Müller has pointed out in his review of the work (*Zeit. f. Psy.*, 39: 113), the known causes of improvement, regarded by the authors as merely auxiliary, such as increase of power of concentrating attention, increase in effort to perfect a memory, decrease in feelings of discomfort and tediousness, improvement of technique of learning—all of these should be logically regarded as "cause" rather than a mysteriously hypothetical psychological action.

The investigation of Thorndike and Woodworth was also carried out according to the test method, its object being to ascertain the result of training with weights, areas, and lengths on the ability to estimate other weights, areas and lengths respectively, that differed from the training series either in size or shape or both. In addition they tested the effect of training, in the marking out of certain letters or misspelled words on a

printed page. One misses, however, those qualities which make Ebert and Meumann's investigation of first rate importance, particularly the careful elaboration of the plan of work, the actual working out of the method in the form of detailed introspections, and the searching and thorough analysis of results. The general conclusions from these experiments are given in Thorndike's "Educational Psychology," p. 91, and are to the effect that "the improvement in any single mental function need not improve the ability in functions commonly called by the same name," and further that "the practice effect seems to make it likely that spread of practice occurs only where identical elements are concerned." It does not appear that the conclusions of the authors of the article are wholly borne out by the figures, the test on estimating the size of surfaces, *e. g.*, showing greater improvement for figures which were unlike the training series in size and shape than for those nearest in either size or shape. The writers state that their experiments were rough and designed to show merely general tendencies, but it is not clear that the figures show anything beyond great individual differences. Had the figures shown a loss of efficiency in executing the tests, the question of transference of function would have still been open. Rough experiments unaccompanied with introspection and so not susceptible of careful analysis are of very little value in work of this kind. The marking out of words is a complicated discriminative reaction, which is not only performed in very different ways by different reagents, but in different ways by the same reagent in one sitting. How different these ways may be will be shown later in an analytical paper by Mr. G. Snow-Gibbs on "Tests in Applied Psychology." On the other hand introspective data gathered by one of the present writers in repeating these experiments (J. E. C.) seem to indicate clearly that the improvement in after tests in marking out letters is not due to the functioning of "identical motor elements," viz., eye movements for example, but to a reduction of the recognition of a word as containing certain letters to its essential process. The process had been relieved of the unnecessary and retarding accompaniments (kinæsthetic and acoustic imagery) noted in the first tests and in the early stages of training. In other words the improvement was due to the general function known as habituation.

At any rate it seemed advisable to attack the problem in such a way that the factor of identical motor elements could play no important part, so that if improvement in efficiency was shown in the test, it could only be attributed to some such general factor as habituation. Accordingly tests were made on sensible discrimination in different modalities of sense and on

discriminative reaction with choice in which the reaction motions common to the test and training series were a negligible quantity. In addition, control experiments were carried along to indicate the effects of test series without the training.

I. Test in Light Discrimination with Training in Sound.

Four reagents were trained in discrimination of intensities of *sound* for 17 days during an interval of 57 days. Each reagent made 40 judgments in each day's training.

Before and after training the reagents were tested in the discrimination of shades of gray, each test consisting of three series, each containing 35 judgments, delivered on 3 separate days.

In the training on sound the stimuli were given with a sound pendulum. The method was that of constant difference, procedure being without knowledge. There were about 10 values for D in each series. The judgments were made in four categories, viz., louder, softer, like, and doubtful. In one pair of series each day, introspections were noted down by the reagent after each judgment; in the remainder the noting of introspections was reserved until after each series was finished.

Discriminative ability at the beginning and end of the training was calculated in per cents of Right cases in the first ten judgments and the last ten judgments made upon six each of the values of D, that is, upon most of the judgments of the first and last two days. No judgments were included where D=o, and "like" judgments for other values of D were regarded as undecided.[1]

The tests on brightness were made with a Marbe color mixer so mounted as to run noiselessly. The experiments took place in a dark room with the light coming from behind the reagents. All the apparatus, including the disk when not exposed, was draped in black. Norm and variable were exposed for two seconds with an interval of four seconds. The attention signal came two seconds before the exposure of the norm. The method was also that of constant differences, without knowledge and the judgments were given in the categories of "lighter," "darker," "like," and "undecided." Introspections were noted by reagents after each series of seven judgments. The order of variables in the test before training was repeated in the after-training test, but in both cases was believed by the reagents to be determined by chance. In order to estimate the possible practice effects of the preliminary test

[1] F. Angell: Discrimination of Shades of Gray, etc. *Phil. Stud.*, XIX, S. 20.

and the interval between that and the after-test, a control experiment was carried along. In this three reagents were given tests in brightness discrimination under conditions identical with those obtaining with the regular reagents, except that 2 instead of 3 days were taken as a basis of comparison. At the end of the interval used by the test reagents for training, *i. e.*, 46 days, the control regents took the second test.

Table I gives a summary of the numerical results for both test and control reagents. From this it will be seen that all the test reagents with one exception show a gain in Right and loss in Undecided judgments after training, and that all the control reagents show a loss in discriminative ability after the interval of rest which was occupied by the test reagents in training. The per cent. of gain for the 4 test reagents was 4, 4, 6, 6, 0, 0, and 27, 5, making an average of 9, 1. The case of the one test reagent who showed no improvement in the after test would seem to be a fair example of the exception which proves the rule, for while the other reagents in the training on sound all showed improvement which amounted to 7, 5, and 15 per cent. respectively, this particular reagent showed no improvement in the judgments of the last two days as compared with the first two, and in fact had fallen off to the extent of three per cent.

The introspections indicate that the discrimination processes were accompanied by much imagery from other domains of sense which in some cases determined the judgment. This imagery was in great part kinesthetic and visual. In addition the sounds seemed to have certain spatial or temporal attributes which at times influenced the judgments. "Variable had a long drawn out sound;" "Variable is a broader sound, that is to say, widely spread;" "Variable comes from a farther place;" "Variable is a small sound." Again bodily impressions may have entered into the act of comparison such as "resonance" or "ringing" in the ears or seemingly deeper seated sensation in the head. "Discriminate effects in the head rather than external sounds." One reagent seemed to compare the intensities of bodily reactions to the sound stimuli themselves or to imagery called up by the stimuli, *e. g.*, the "flash of a bicycle lamp."

Besides these various reproductive factors which accompany the essential sound-discrimination process, there are disturbing factors of a general nature, such as strong expectation for a loud or weak sound, and the varying intensity of the state of attention. If a loud sound is strongly expected, a weak one may seem weaker; if a weak one is expected a loud one may seem louder. If the intensity of the state of attention is sought to be kept at a maximum, it will vary greatly, a result

TABLE I.

Comparison of Test and Training Judgments for Test Reagents and of Test Judgments for Control Reagents.

Test Reagents.

A.	Right Judgments.	Aw	Na	Ya	Cr	Total.
Tests.	No. R. Before training.	60	46	47	46	119
	" " After "	64	52	47	68	231
	Diff.	+4	+6	0	+22	+32
Training in sound.	No. R. 1st 2 days.	22	22	26	27	97
	" " last 2 days.	31	25	24	34	114
	Difference.	+9	+3	—2	+7	+17
B.	Undecided Judgments.					
Tests.	No. U. Before training.	16	38	22	27	103
	" " After "	13	19	28	6	66
	Difference.	—3	—19	+6	—21	—37
Training in sound.	No. U. 1st 2 days.	18	23	16	16	73
	" " last 2 days.	9	16	20	8	53
	Difference.	—9	—7	+4	—8	—20

Control Reagents.

C.	R. and U. Judgments.	Rl	An	Wr		Total.
Tests before and after interval without training.	No. R. Before interval.	41	31	46		118
	" " After "	38	30	43		111
	Difference.	—3	—1	—3		—7
	No. U. Before interval.	10	16	2		28
	" " After "	13	15	7		35
	Difference.	+3	—1	+5		+7

due both to its own rhythm and to the varying subjective conditions upon which it depends.

Improvement seems to consist of divesting the essential process of the unessential factors, freeing judgments from illusions, to which the unnecessary and often fantastic imagery gives rise, and of obtaining a uniform state of attention which is less than a maximum: "Judgment does not require strained attention. All are quite certain or satisfactory. Don't see what the process is now—seems automatic" (Cr. May 12, IV). And uni-

formity of direction of attention may also result: "Am able to abstract from visual image of the apparatus entirely, and yet refer the sounds to external stimuli. This seems to take the least effort and is more satisfactory" (Cr. May 17, IV). Many of the introspections of the various reagents, near the end of training, were "No imagery."

Our conclusion from the experiment, therefore, is that efficiency of sensible discrimination acquired by training with sound stimuli has been transferred to the efficiency of discriminating brightness stimuli, and that the factors in this transfer are due in great part to habituation and to a more economic adaptation of attention, *i. e.*, are general rather than special in character.

II. Reaction with Discrimination and Choice.

In the experiments with discrimination and choice identical motor elements were eliminated by employing different kinds of stimuli and different forms of reaction, although in both cases the sense of sight received the stimuli, and reactions were made by movements of the hands.

The object of the experiment was to determine the effects of practice in one form of activity upon efficiency in another. This influence could show itself either in lowering reaction time in the latter, or making it more regular, or both,—which would be apparent in a practice curve of the tested ability.

The training was accomplished by about 15 exercises in sorting cards. Four reagents took the training which was scattered through a space of about 40 days. In this time about 4,000 cards were distributed by each reagent (Cl 4,200, Al 3,800, Cr 5,200, Bs 4,000).

Before the training in card-sorting the reagents were tested for five days on "typewriter reactions," aggregating about 3,000 reactions in each case (Cl 2,900, Al 2,900, Cr 2,700, Bs 3,100), and after training in card-sorting there came the after test for three days, giving about 1,800 reactions (Cl, Al, Cr, 1,800, Bs 1,700).

For the training a Jastrow card-sorting cabinet was used with 6 compartments; the cards were made of smooth, buff-colored Bristol-board (77x52 millimeters). In the centre of each card a colored rectangle was painted in water color (12x 52 mm.), six colors being used—red, blue, black, and brown in a rather deep shade, and yellow and green in tints. The cabinet stood at a convenient height, and was entirely covered with black cloth.

In card-sorting the reagent stood at the cabinet and held in his left hand a pack of 50 cards, from the top of which he would grasp a card, turn it up sufficiently to see its color on

the under surface and drop it into its appropriate compartment. In about the middle of the training the color labels were removed from the compartments.

The cards were arranged in packs of 50, according to 12 different orders in which each color appeared about as often as every other, each preceding and succeeding the other about equally often; no color recurred with less than two intervening colors.

The assignment of colors to the compartments was so made that the spatial relations of the latter would not correspond with the complementary or spectral relations of the former.

For the "typewriter-reaction" a Blickensderfer typewriter was used, fitted up with a screen through which but one letter could appear at a time. Series of letters were printed with the typewriter and cut into strips which could be clipped to the "scale-bar" and moved behind the screen by the "carriage." The spacing of the letters in the series and of the typewriter "action" being the same, the strip could be so adjusted that every time a key was struck, a new letter appeared through the screen.

The various series were made up of four letters in such a way that all the letters appeared about the same number of times, and each letter preceded and succeeded every other letter and itself about equally often.

In the "typewriter-reaction" the reagent sat with his hands in position over the lower bank of keys on either side of the middle, and reacted to the letters as they appeared through the screen—*a* and *t* on the left and *e* and *n* on the right.

The time of reaction to each letter was recorded in another room upon a kymograph. The typewriter itself, of course, making records of the reactions, which could be inspected for accuracy.

Control Experiment. In order to determine more definitely the possible effects of the training in card sorting in the "typewriter-reactions," three reagents were trained in the "typewriter reaction" three days before and two days after an interval of 45 days during which no training was taken. In both the test and control experiment, efficiency was estimated by the time involved and in number of errors in each 100 reactions.

Table II gives the daily average time and error for 100 reactions on the typewriter for the test reagents, both before (A) and after (B) training in card-sorting, and Table III gives like data for the control reagents, both before (A) and after (B) an interval without practice.

The quantitative results as laid down in those two summaries seem to be ambiguous: the reagents trained on the card-sorting show indeed an increase in efficiency in the after-test on the

TABLE II.

Test Reagents. Daily average of time (in sec.) and errors for 100 reactions on Typewriter.

A. Before Training.

Cl		Al		Cr		Bs	
sec.	errors.	sec.	errors.	sec.	errors.	sec.	errors.
71	2	94	0	73	3	99·5	5
76	0.9	93	4	76	3	87·3	3
73·5	1.1	80	3	71.2	3·5	84	4·5
67.4	1	73.1	6.3	69.1	3	80.1	5·3
69	1	72.2	4·5	69.1	5	77·9	4·3
63.3	0.8	72.7	7	67	4		

B. After Training.

63.1	1	65.2	8	66.4	4.5	70.7	8
61.3	1	62.9	11	62.1	4·5	69	3·3
60.4	1	61	13	61.7	5·4	66.3	6

TABLE III.

Control Reagents. Daily average of time (in sec.) and errors for 100 reactions on Typewriter.

A. Before Interval.

sec.	errors.	sec.	errors.	sec.	errors.
90.7	5	141.8	4	87	1
74.1	7·5	116·5	1.3		
74	6.3	96.1	1.5		

B. After Interval.

70.7	4·5	90·5	1.3	80.5	1
66.2	7	86.2	1.3		

typewriter, but most of them show an increase in errors. Moreover the control reagents also show an increase in efficiency after their incubation period. In both cases, however, an increase in speed was to be expected, for the common belief in beneficial effects of incubation periods on bodily activity has been amply confirmed by numerous investigations on practice and fatigue. The question of the effects of the training in card-sorting must, therefore, find its answer in an examination of the errors and of the introspective evidence. The obvious explanation of the increase in speed accompanying the decrease in accuracy is that as the reagents increased in manual dexter-

ity they became more careless in co-ordinating the visual impressions with the reactions; in short, that accuracy was sacrificed to speed. But a study of the errors shows that the obvious explanation is not correct, for taking from each of the eight test days the series of reactions showing the maximum and minimum number of reactions respectively, we get

TABLE IV.

Table of Relation of Reaction Times to Max. and Min. Number of Errors.

Cl	with	0,06	errors	averages	66,4	sec.	for	100	reactions
	"	2,3	"	"	67,9	"	"	"	"
Al	"	4,7	"	"	72,0	"	"	"	"
	"	9,9	"	"	73,0	"	"	"	"
Cr	"	1,4	"	"	65,6	"	"	"	"
	"	5,9	"	"	68,4	"	"	"	"
Bs	"	2,3	"	"	77,8	"	"	"	"
	"	7,9	"	"	81,6	"	"	"	"

The figures from which these averages are taken occur irregularly throughout the several series of the eight days, so that it cannot be urged that the correlation of a smaller number of errors with greater speed is due to each day's practice effects. As a matter of fact in the majority of the eight cases, the maximum number of errors occurred in the later series of the day. The introspections show the reasons for this inverse relation existing between speed and error tendencies. Cr notes "Made mistake and was bothered thereby;" "Errors result in confusion and pauses." Al remarks, "The large number of mistakes impedes the rapidity as one is troubled by them;" Bs says "Mistakes were noticed and caused confusion at the time." Cl says "The time I spent in thinking of a mistake caused a delay." From both tables and introspections we see that the increase of errors in the after test can be due only in a small part to carelessness accompanying greater skill in manipulation, and the question then arises, to what is it due?

There were probably at least five special causes for the errors: (1) Lack of co-ordination between the letter and its proper reaction, (2) Anticipation of a letter, in which case the reaction took place before the letter was cognized, (3) False recognition of the letter, (4) Reaction incited by rhythm without cognition of letter, and(5) Misplacement of the fingers on the keys. The fourth cause is probably the chief factor in the increase of errors in the second training.

As the reagents acquired more and more skill on the typewriter, a strong tendency developed towards rhythmic series reactions which resulted not in false or mistaken reactions, but

in mechanical reactions; that is, the rhythmic tendency was strong enough to overcome the voluntary effort towards a discriminative reaction. The effect of this power was to produce the confusion referred to above and in general to lengthen the total time for the series. A general source of error for the after-tests was the fact that they came in the closing days of the semester when the burden of the examination period fell heavily on instructors and students alike. The introspections give altogether too full evidence of the condition of general fatigue with which the reagents entered on the tests after training.

There remains to be discussed one effect of the training which cannot be shown by tables, and that is the effect of training on ease of accomplishment. The figures for the after-test on the typewriter show that the test reagents made very little gain in speed for the three days of the test itself. Indeed the skilled reagents Cl and Cr had arrived at their maximum efficiency one or two practice days before the training period, and if the card-sorting had favorably affected the speed of the typewriting it could not be shown by numerical results. But the introspections show a very unexpected increase in the ease of accomplishment following on the card-sorting.

On the first day of the second test Cl remarks, "Sight of letter produced the reaction movement without my thinking of my fingers or of the sight of the keys." Al remarked, "No headache, no nausea as before card-sorting," "Much easier than at first;" "General background of feeling is probably not unlike that of the card-sorting test, but I did not think of the card-sorting test during the trial." Cr said: "Process was surprisingly automatic and was accompanied with ease," "Seems more automatic than ever before, and even more so than the card-sorting. I do not pay the slightest attention to the fingers on the keyboard when the process is going best. . . . It appears that the old associations have not only not been interfered with by forming new ones in card-sorting, but that they have become firmer and action upon them more ready and automatic than it was before or than it was in card-sorting" (April 27). On the last day of the typewriter training before card-sorting began, Bs remarked, "Pauses between letters caused by having to think which finger I should put down," and on the first day of training after card-sorting, "Seemed more natural than I thought it would," and the next day, "Seemed more natural to react to-day, demands less attention, tendency to become automatic."

The introspections of the Control reagents, on the other hand, none of whom was familiar with typewriting, show that while some ease and facility were experienced in the period be-

fore training, the after-test seemed unexpectedly "difficult" and "unhandy;" Mn stated in the after-test that "Reacting seemed difficult," "Seemed to have to stop to think which finger was to react to the different letters." Ge in the period before training said, "The reactions are becoming more automatic;" and in the after-test that he "looked at a letter not knowing what to do," and that "combinations of letters here were particularly unhandy." Feelings of discomfort and difficulty following on the interval without practice of any kind emphasize the conclusions of the preceding paragraph, viz.: That the training in card-sorting is the cause of the increased ease and facility experienced by the regular reagents in the second trial in typewriter-reaction.

Conclusion. We may conclude, therefore, from the results of this experiment, that training the activity of Reaction with Discrimination and Choice by sorting cards into compartments has increased the facility of a like activity in both speed and regularity in "typewriter-reaction" (a) noticeably, in two cases, after the latter had become automatic, and (b) markedly in two others, in the course of practice.

The cause of transferred facility could not have been identical motor elements. In the "typewriter-reaction" the eyes rested sharply fixed upon one spot upon the screen, while in the card-sorting reaction the eyes moved rapidly about over the compartments in the cabinet, merely glancing at the colors. The differences in manipulation between tapping keys with forefingers and sorting cards are, of course, patent. To what, then, is this improvement due?

According to the introspections of the regular reagents on their card-sorting training, the process of reaction is variable. At the beginning of training they matched the color of the cards with the labels on the compartments; then to increase speed a system of mnemonics is employed, designed to form associations in the mind between a compartment and its color; this system then goes through a process of mutation,—becoming abbreviated, changed in part, supplemented, or is superseded by another; finally, through repetition, reactions to particular compartments become co-ordinated with their respective colors and are made directly—free from any "system" except in rare cases. Synchronously with the growth of these co-ordinations adventitious processes, such as pronouncing the name of the color when cognized, movements of the whole body and useless movements of the hand, decrease to a minimum.

As regards the "typewriter-reactions," the introspections of both regular and control reagents show that the processes of reaction go through like stages, except that the mnemonic

systems arise sooner and change oftener. No two systems are alike. But all finally give way to the direct reaction which has been co-ordinated with its letter. Again, adventitious processes, such as pronouncing letters upon cognizing them, visualizing keys, fingers, or their order, likewise decrease to a minimum.

Different as the typewriting and card-sorting reactions are in details the course of experimentation developed a general condition common to both, *i. e.*, *the habit of stripping the essential process of unnecessary and complicating accessories.*

Introspections further show that in any one series several systems of mnemonics may be operative; there may be also some direct reactions due to the co-ordination of stimulus and reaction; in one part of the series one stimulus causes difficulty and elsewhere another stimulus, while some stimuli seem harder than others throughout the whole series. Improvement here seems to consist in resolving the reaction process to a single type (except in so far as reactions become direct), and in attending more closely to difficult stimuli until their reactions become as ready as those to the other stimuli.

Again, introspections and records show that, even after a mnemonic system has been successfully applied and has served to bring stimulus and reaction to a fair degree of co-ordination, lapses of attention occur during which the "mind is a blank," and the drum records abnormally long reactions. Improvement here consists in keeping attention upon the matter in hand so constantly that the irrelevant stimuli are unnoticed.

We find, therefore, the causes of the transference of facility to be: (a) the formation of a habit of reacting directly to a stimulus without useless kinesthetic, acoustic, and motor accompaniments of recognition, which results in (b) an equitable distribution of attention to the various possible reactions so as to be about equally prepared for all; and (c) the consequent power of concentrating the attention throughout the whole series without distraction.